DEFLECTING SYNCHROTRON RADIATION FROM THE INTERACTION REGION OF A LINAC-RING LHeC*

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Abstract

In a linac-ring electron-proton collider based on the LHC, before and after the collision point the electron beam can be deflected with weak dipole magnets positioned in front of the superconducting final quadrupole triplets of the 7-TeV proton beam. Significant synchrotron radiation may be produced when the electron beam, of energy 60-140 GeV, passes through these dipole magnets. As an alternative or complement to shielding, parts of the synchrotron radiation could be extracted together with the electron beam. We propose using mirrors with shallow grazing angle to deflect the synchrotron radiation away from the proton magnets. Various LHeC options are considered. Limitations and challenges of this approach are discussed.

INTRODUCTION

Linac ring type LHeC is a collider project to collide an electron (positron) beam of 60-140 GeV energy from a linac with the LHC 7-TeV proton beam [1]. The electron and proton beam sizes are matched at the interaction point (IP), $\sigma_p^* = \sigma_e^*$. On the design of the LHeC beam parameters, the starting point is the LHC design values for the proton rms normalized transverse emittance and bunch length. The proton and electron IP beta functions are taken to be 0.1 m and 0.12 m respectively[2]. Some important parameters are listed in Table 1. More detailed parameter set can be found at Ref. [3].

Table 1: IP beam parameters of protons and electrons.

	protons	electrons
energy [GeV]	7000	60
tr. geom. emittance $\varepsilon_{x,y}$ [nm]	0.50	0.43
IP beta function $\beta^*_{x,y}$ [m]	0.10	0.12
rms IP beam size $\sigma^*_{x,y}$ [μm]	7	7
beam current [mA]	430–580	6.6

The LHeC detector is expected to have 3.5 T solenoid extending ±6 m from the interaction point (IP) [4]. The free length, l^*, between the end of the last quadrupole and the IP is taken to be 10 m. We don't place deflecting dipole magnet at the region of ±1.5 m on either side of the IP since the most important region for the inner detector will take place [4]. Head-on collisions can be provided by dipole fields as prescribed at Table 2. We leave 1 m free space between the end of the dipole and the entrance of the proton triplet (for shielding) and a 3-m gap around the IP (for the inner detector). In order for the 7.5-m long dipole to displace the 60-GeV electron beam at the quadrupole entrance by 80 mm from the proton beam axis by a dipole field causes significant synchrotron radiation. Figure 1 also indicates the computed minimum stay clear corresponding to beam envelopes of 10σ for the electrons and 11σ for the protons, respectively, with an additional constant radial margin of 10 mm for orbit errors, misalignments, optics errors etc.

Table 2: Deflecting magnet specifications

Distance [m]	Bending radius [m]	Field [T]	Critical Photon Energy [keV]
$-20 \div -1.5$	520	0.385	923.3
$1.5 \div 1.945$	200	1.	2400.5
$1.945 \div 9$	470	0.426	1021.5

Synchrotron Radiation

With a deflection angle of 34 mrad on either side of the IP, the number of photons emitted per bunch passage is 8 × 10^{10}. Their critical energy of 923.3 and 1021.5 MeV nearly equal the threshold for pair creation. For 6.6-mA beam current the average SR power from the downstream dipole magnet is 87 kW. More than one seventh (13.45 kW) will enter the proton beam pipe inside the first quadrupole Q1, and more than half of the total (50 kW) will pass into the electron-beam exit channel. The peak SR power density at the absorber shield is 885 W/mm^2. The surface of the magnet-coil protection shield should be sloped to reduce the power density and to make it acceptable for ordinary materials like copper. An acceptable number is 10-20 W/mm^2. The SR absorbers have to be water cooled.

To decrease above power limitations, we can introduce mirrors to reflect some radiation with a shallow grazing angle into electron beam pipe.

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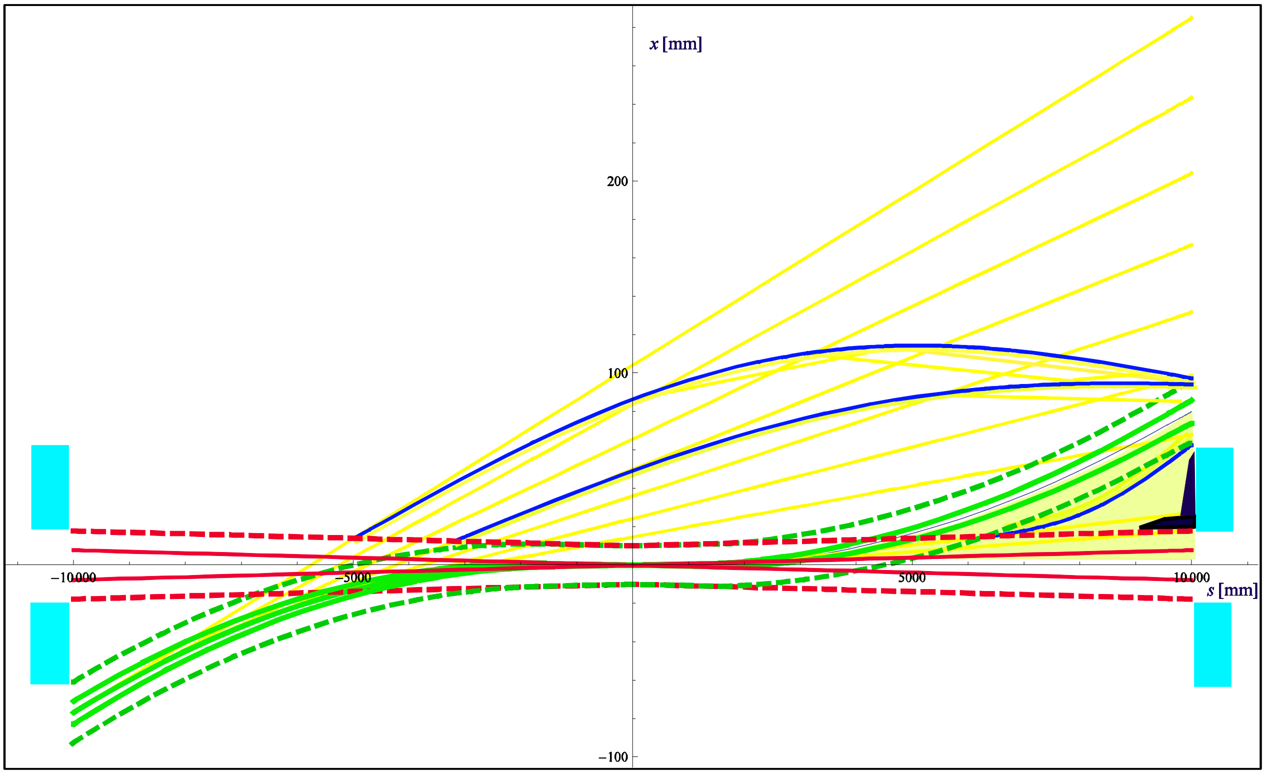

Figure 1: Beam envelopes of 10σ (electrons) solid green] or 11σ (protons) [solid red], the same envelopes with an additional constant margin of 10 mm [dashed], the synchrotron radiation fan and reflected photon beams [yellow] from mirrors [blue], and the approximate locations of the proton triplets [light blue], and possible location of the absorber shield [black].

X-RAY MIRRORS

Reflection properties of two different mirror sets are investigated and thought to be usable. These two materials are gold and NiO. The grazing angle, reflectivity and photon energy behaviours of these mirrors are presented in Figure 2 and 3. Spectra of bending magnets are shown in Figure 4. Also the cross section for interactions of the high energy photons with gold and NiO is presented in Figure 5. As seen from Figure 5, the cross section is very high at low energies. So, photons at this regime deposit more energies. Therefore one can reflect the most of the photons with mirrors with reasonable grazing angles.

DEFLECTION OF PHOTONS

Because of the distance, it is easier to reflect half of the synchrotron radiation power (namely, critical photon energies) produced at upperstream deflecting magnet with right grazing angle. Also, one can use more than one mirror as seen at Figure 1. For this one has to reflect the radiation with grazing angle about 0.06 mrad. Also, it is possible to reflect quarter of radiation power produced at downstream magnets with grazing angles between 0.6-0.8 mrad corresponding to photon energies of less than 200 keV. Another approach might be to bore small holes on triplet and channelling photons to these holes.

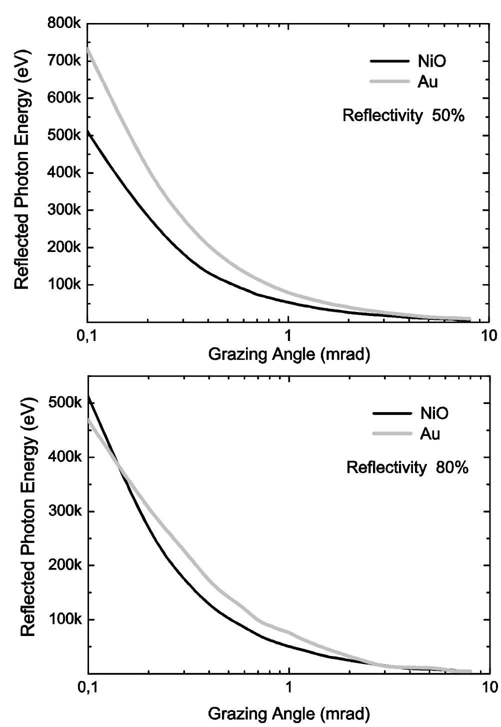

Figure 2: The photon energies and grazing angles with 50% and 80% reflectivity for gold and NiO.

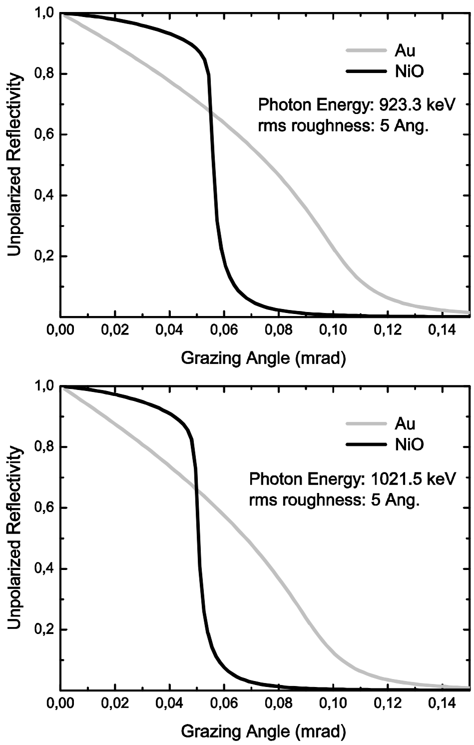

Figure 3: The photon reflectivities and corresponding grazing angles for 923.3keV and 1021.5keV photon energies for gold and NiO.

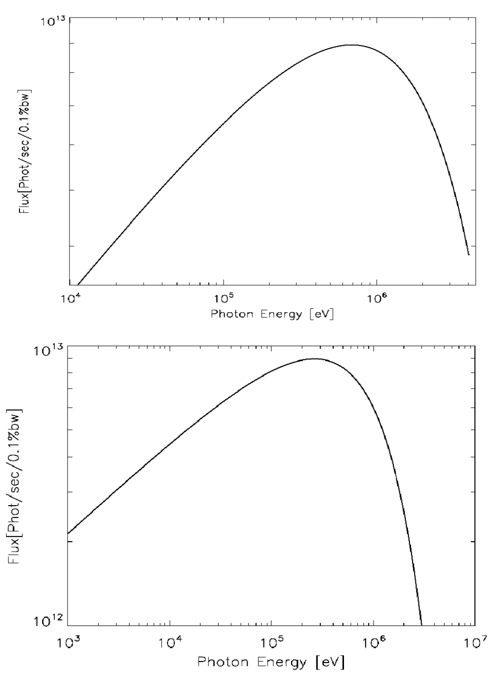

Figure 4: Fluxes of synchrotron radiation emitted from bending magnets with 1 T and 0.385 T.

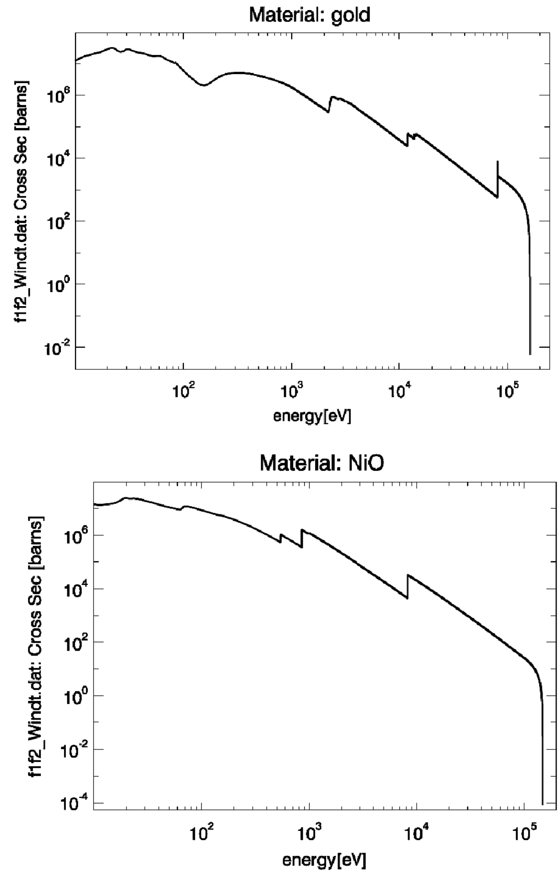

Figure 5: The cross sections for interactions of the high energy photons with gold and NiO.

CONCLUSION

Above scheme can be applied to LHeC with 140 GeV electron energy option. Since space limitation version with 140 GeV is less demanding, it is easier to shape the mirror system for need.

Mirrors are placed with shallow angles, therefore power density on the surface will be on limits. Still, it is possible to cool mirrors from behind.

REFERENCES

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[4] 2nd ECFA-CERN LHeC Workshop, Divonne, Sept. 2009.